PB-237 777-T

MARINE MOLYSMOLOGY: THE PRIMARY PRODUCTION OF EXPERIMENTAL ECOSYSTEMS SET UP IN THE RANCE RIVER ESTUARY. EFFECT OF CRUDE OIL

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November 1974

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EPA-TR 86-75

PB 237 777-T

MARINE MOLYSMOLOGY: THE PRIMARY PRODUCTION OF EXPERIMENTAL ECOSYSTEMS SET UP IN THE RANCE RIVER ESTUARY. EFFECT OF CRUDE OIL.

[Molysmologie Marine. De la production primaire d'ecosystemes experimentaux etablis dans l'estuaire de la Rance. Effect d'un petrole brut.]

by

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Published in C.R. Acad. Sc. Paris, Vol. 278, May 13, 1974, pp. 2531-2534.

Crude oil (Kuwait) discharged into experimental ecosystems resulted in a sharp 50% decrease in primary production the day after pollution; this began to lessen the following day (25%) and disappeared on the third day. The fourth day marked the onset of toxicity which gradually increased until primary production was almost totally inhibited one week after pollution. This inhibition phase lasted ten days. During the rest of the experimental period, the primary production of the polluted ecosystems was approximately half that of the control ecosystems.

Toxicology research is generally performed in the laboratory on a few constituents of the ecosystems considered (autecological viewpoint). However, the complementary, synthetic aspect of ecology which consists in analyzing the overall effect of a pollutant on an ecosystem should not be overlooked (synecological viewpoint); here research is more difficult,

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Translated for NERC-Library, EPA, by LEO KANNER ASSOCIATES, P.O. Box 5187, Redwood City, California 94063, (415) 365-3046, November 1974.

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especially when complex pollutants such as petroleum are involved, and thus this type of research is performed less often [2-6]. In this case, it is obviously impossible to make a detailed analysis of the changes pollution introduces in the extremely complex relationships between the species populating a biotope; the functioning of an ecosystem must thus be considered from a broader standpoint. The present study, therefore, will deal with the effect of oil on one of the metabolistic elements of the whole (photosynthesis).

Experimental Procedure

The method of experimental pollution of ecosystems in situ consists in purposely polluting certain fractions of the natural environment. Physico-chemical and biological parameters are analyzed before and after pollution.

To facilitate research, it is usually necessary to enclose these fractions artificially. Experimental ecosystems are thus established: some are polluted, and others which are not polluted serve as controls. The number of ecosystems used will depend on the possibilities for chemical and biological analysis and statistical processing of the results. In an aquatic environment, the process of building an experimental ecosystem consists in enclosing a quantity of water, with or without the subjacent sedimentary layer. In our experiments, the water was isolated by means of simple and relatively inexpensive devices which consisted primarily of "rilsan" bags or sheaths (impermeable to hydrocarbons) kept in place by weights and polyvinyl chloride braces. Thus natural temperature and illumination conditions were maintained.

The tests were performed in October 1973 in the Rance River estuary, upstream from the tidal power plant. The water behind this plant forms a

marine reservoir sheltered from swells. After a preliminary study of the hydrobiological conditions of the estuary [1], an experimental station consisting of a pontoon, as described in a previous article [4], was set up. With this pontoon it was possible to raise the experimental devices to avoid waves and facilitate sampling and equipment storage. We prepared a type of device consisting of rilsan bags 0.40 m in diameter containing 60 liters of seawater. Most of the zooplankton was initially removed from this seawater by passing it through nylon cloth with 184 µm openings, and its biocenosis was therefore simplified to consist primarily of phytoplanktonic elements. The bags were protected by large translucent polyethylene vats, necessitated by the strong currents produced by the tidal power plant.

The vats were covered with plexiglass plates mounted on square wooden frames. This protective system prevented precipitation and waste from the numerous seabirds landing on the pontoon from entering the ecosystems. It should be noted that the plates, in a higher position than the vats, were not hermetically sealed, the air instead circulating normally through the four corners of the frame.

Fifteen devices were used in this study: five were not polluted and served as controls, five others were polluted with 100 ml oil (Kuwait), and the last five were polluted with 100 ml of an oil emulsion and an experimental dispersant (30%). The pollution was introduced at 4:00 p.m. on September 25, a few hours after the devices had been placed in the water.

The following parameters were analyzed by the CNEP[1] Laboratory: dissolved oxygen concentration, total bacteria, hydrocarbon-oxidizing bacteria, and qualitative and quantitative development of residual hydrocarbons. The results

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[1] Centre National d'Etudes pour la Protection des Aliments, Matériaux et Etres Vivants; National Research Center for the Conservation of Food, Materials and Life Forms. Our research was funded by this laboratory.

of these analyses will be published subsequently and compared with measurements of the primary production of the different ecosystems, whose general characteristics will be given here.

Primary production was evaluated by the carbon 14 method. The samples were incubated in the laboratory for a period of four hours (12:30 - 4:30) under 10,000 lux illumination at the water temperature measured prior to sampling. The activity introduced into the flasks was 10 µCi; counts were made by liquid scintillation [7]. The results were expressed as carbon production per cubic meter per hour of incubation.

$$P\ mgC\ m^{-3}\ h = \frac{a \times 1.05 \times B}{A \times N}$$

a: C^{14} assimilated in dpm; 1.05: isotopic correction factor; B: dissolved CO_2 content (25 mgC/ℓ); A: activity introduced in dpm; N: number of hours of incubation. The water samples needed for analysis were taken from all the ecosystems at 10:00 a.m. by means of a Wab pump, changing the site of water intake from one sample to the next: samples were taken from the surface (under the oil layer) and from the bottom to reveal possible differences in toxicity at these two levels. Samples were taken every day during the first week and at regular intervals thereafter.

The primary production was measured per sample, and thus per ecosystem (one illuminated flask and one dark flask). The resultant value[2] was then determined for each of the three groups (control, oil, emulsion) from the five ecosystems.

On October 4 the water in the estuary was agitated to an unusual extent, and as a result, three control ecosystems which had taken in a given amount

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[2]Confidence interval for $P = 0.05$.

of water had to be eliminated. From then on, therefore, the control group consisted only of the two remaining ecosystems.

At the same time that the water in the ecosystems was being sampled, samples of the surrounding open water were taken at a depth of 1 m at a fixed point located a few meters from the pontoon. Five photosynthesis measurements were performed on each sample (five illuminated flasks, five dark flasks). Fig. 3 shows the variations in primary production[2] over the experimental period.

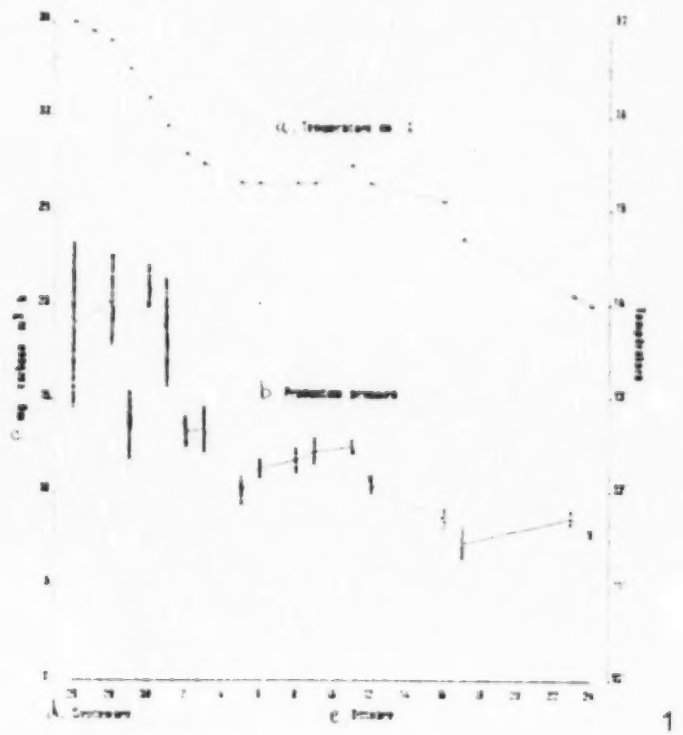

Fig. 1. Relationship between primary production and temperature of water at the experimental station.

Key: a. Temperature in °C.
b. Primary production.
c. mg/carbon/m^3/h.
d. September.
e. October.

[2]Confidence interval for $P < 0.05$.

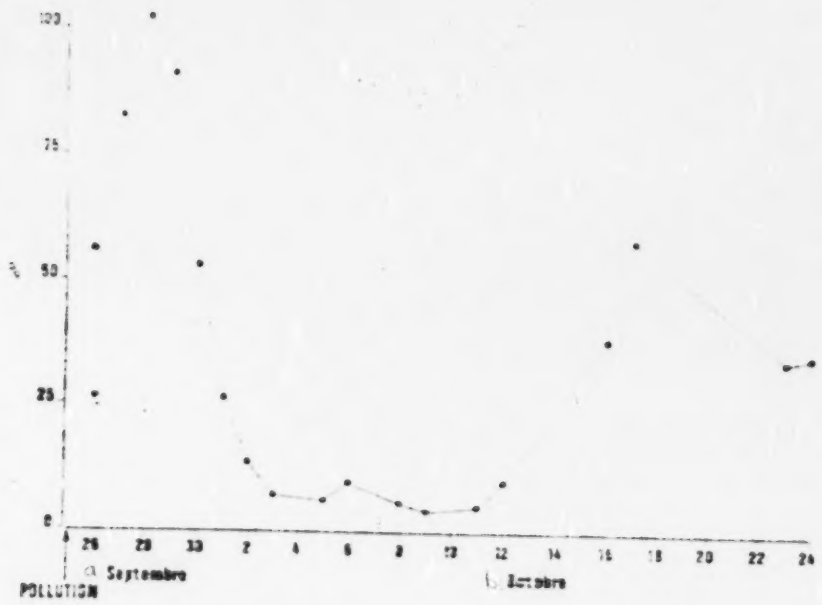

Fig. 2. Effects of crude oil (Kuwait) on the primary production of five experimental ecosystems. The results are expressed as a percentage of the primary production of the control ecosystems.

Key: a. September. b. October.

II. Results and Discussion

In October, a gradual decrease in primary production was observed at the experimental station which seemed to be very closely related to variations in the temperature of the water (Fig. 1). Thus these two parameters may be seen to undergo a sudden drop between the end of September and October 2, followed by a more stable period of one week and ending with a gradual decrease in temperature and primary productivity.

The same phenomenon occurred in the control ecosystems. The primary production, initially similar to that of the surrounding open water (20 $mgC/m^3/h$), decreased to 5 $mg/m^3/h$ one week later. This value remained constant until the end of the experimental period. Thus the drop in primary production for these ecosystems was much more rapid than in the open water, and it also

stabilized at a lower level. This difference may be explained by the lack of effective replenishing of nutritive salts in a closed environment.

Fig. 2 shows the primary production of the ecosystems polluted with oil as a percentage of the primary production of the control ecosystems; the results obtained at the surface and at the bottom are given alternately. On the first day after pollution (surface sampling), there was a sharp decrease (50%) which lessened on the following day (25%) and disappeared on the third. During this period, the oil was spread uniformly over the surface of the ecosystems. Subsequently it began to adhere to the walls of the rilsan bags and thus had little further effect on the passage of light. Since the samples were incubated for primary production measurement in front of a row of lights in the laboratory, illumination could not have had any direct influence. The initial retardation of primary production must have resulted instead from the presence of light, especially toxic fractions of the oil in the water, which afterwards disappeared quickly due to their volatility.

The fourth day marked the onset of toxicity, which gradually increased to the point where primary production was almost completely inhibited one week after pollution. This inhibition phase lasted for ten days. During the rest of the experimental period, the primary production of the ecosystems polluted with oil was half that of the control ecosystems. In addition it should be noted that similar results were obtained from the surface and depth samples, indicating that the toxicity was on the same order at both levels.

The incorporation of dispersants into oil can only increase toxicity. This was in fact what we observed here: the primary production of the five ecosystems polluted with an experimental oil-dispersant mixture was zero the day after pollution and remained zero for the entire experimental period.

Similar results have been observed with most commercial dispersants in research performed at Dinard in 1971 and 1972.

In addition, it should be noted that the maximum toxicity of the oil used alone did not appear immediately, but only after a few days. Thus short-term tests will result in an underestimate of toxicity. These results indicate, as we have already poirted out [2], that in situ experimentation in ecosystems should be considered a complementary method to tests of toxicity performed on the various components of the ecosystem .

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